We have found that the demonstrations are most durably set up if flexible metal tubing is used to connect the gas-cocks with the smaller apparatus, and if short straight pieces of large-bore rubber tubing connect the large openings of the iron pipe with the tonometers. Bends in the rubber tubes leading to the tonometers are avoided by permanent elbows fixed to the vertical intake-openings. A large 1½-in. pipe-flange, bearing a 1½—1-in. reducing ell and a nipple, has been screwed to the bottom of each tonometer over the inlet opening; the length of rubber tubing can thus be slipped directly over the horizontal nipple without bending.

II. Delboeuf Disks and the Kirschmann Photometer

By E. G. Boring

Of the three methods described by Titchener[1] for the experiment on the application of the Method of Equal Sense Distances to brightnesses, the first, as Titchener points out, is mechanically unsatisfactory, and the third, which requires three motors or a triple color-mixer, is often impracticable. The Delboeuf disks of the second method are made by passing black sectors on white cardboard. It is difficult to cut these sectors exactly, and still more difficult to paste them correctly, as they must be perfectly centered and separated by 180° with an error of less than half a degree. If the space order is to be varied, two disks have to be cut. The movable sector can be made to use with both space orders, but must in that case be notched in a way that makes it easily breakable. Both cardboard and black paper are often smudged in pasting. With use the pasted black paper is likely to get shiny, the cardboard dirty, and the sector broken. An accident to any one of these three pieces means the remaking of all three, if the tone of the black and the white is to remain the same. Even when the experiment proper has been successful, it sometimes happens that the student gets the black sample pasted on the Kirschmann photometer in such a way that it does not exactly resemble the black of the disks. In general we have found that every pair of students requires a new set of disks, which take a couple of hours to prepare.

We have therefore substituted in the Cornell Laboratory the method described by Martin[2] for the contrast experiment. We cut disks of three sizes from each of the two gray papers which have been selected as the terminal stimuli. The middle-sized disks are slotted and fitted together; when mounted concentrically on a mixer, with a small disk of the one gray and a large disk of the other, they constitute the variable ring. Space order is reversed by substitution of the other (large and small) disks. The method saves the time required for cutting on the disk-cutter arcs of limited length, for laying out radii at exact angles, and for pasting the paper on the disks; and it avoids the errors arising from poor spacing and centering, and from the frequently non-uniform appearance of a pasted black paper. Moreover, the use of gray papers instead of black and white makes an accurate adjustment of the variable easier; for the total range of

[1] E. B. Titchener, *Experimental Psychology*, II, i, 87-90.
[2] L. J. Martin, *Amer. Jour. Psychol.*, 24, 1913, 33f.

variation is now 360° instead of a comparatively small sector (*e. g.*, 30° in the disk figured by Titchener).

All the objections urged against the Delboeuf disks apply with equal force to the Kirschmann photometer.[3] The photometers are difficult to make, and soon get dirty. The samples of paper to be tested, even when accurately cut, are difficult to center and may be smudged in pasting. We have accordingly applied Martin's arrangement to the photometer. If the motor is rapid, it is not necessary to cut two sector openings in the disk; one opening of 180° will not flicker. Thus we cut in a white cardboard disk (diam. 26 cm.) one 180° sector of an annular ring of radii 9 and 6.5 cm. (The arc of the smaller radius need not be cut carefully, since it lies beneath the next disks.) A disk of the paper to be tested, coupled with a disk of the white cardboard (diam. 14 cm.), forms the concentric variable ring which lies inside the black (hole) and white (cardboard) ring. A small white cardboard disk (diam. 10 cm.) fills the center. These disks can all be cut on the disk-cutter with so little handling that they are not likely to get dirty before use. No pasting is required, and centering is exact. But one incomplete arc (instead of five) has to be cut. The fine adjustment can be added, as usual, if it is desired. For very light grays it is well to have a large disk with a 90° annular sector instead of the 180° sector.

It is necessary, in using the Kirschmann photometer, carefully to fix the position of the observer so that he shall look directly into the long black tube, since the wall reflects some little light. We have found that a large black box (18 by 18 by 36 in.), with a circular hole cut at one end, makes a dark chamber whose sides are not brought into the observer's field of regard by any ordinary accidental shift of position.

III. Urban's Tables and the Method of Constant Stimuli

By E. G. Boring.

F. M. Urban's recent publications on the psychophysical methods, and in particular his *Hilfstabellen*, have so revised the procedure of the method of constant stimuli that the account in Titchener's *Quantitative Manual* is no longer adequate. In the Cornell Laboratory we have found it necessary to supplement the text of the *Manual* by individual instruction in the use of Urban's tables. The student cannot ordinarily be sent directly to the original articles, for the mathematics (and the German!) are usually beyond him. We propose, therefore, to print an elementary account of the method of constant stimuli in its present form. We shall use little mathematics. The instructor or student will, however, find in the notes at the end of this paper an indication of sources.

§ 1. The Psychometric Function

If for every member of a series of stimuli it is possible to give the one or the other of two judgments, and if it be found that the frequency with which the one judgment is given depends upon the value

[3] Titchener, *op. cit.*, 35ff.